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The Physico Chemical Properties of Coal Mined Soil and Soybean Yield under Ameliorant Residue of In Situ Bituminous Coal and Its Coal Impurities

Khairul*, Khaidir Ajidirman, Sunarti
University of Jambi, Indonesia; Kampus Pinang Masak, Mendalo Darat, Jambi, Indonesia
Jalan Raya Jambi - Ma. Bulian KM. 15 Mendalo Indah 36361
Pascasarjana Magister Agroekoteknologi

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**Corresponding author*:
E-mail: irulkarel@gmail.com

ABSTRACT

Application of slow decomposed organic ameliorants is expected to have a long-term impact on improving soil Physico-chemical properties. The source of in situ organic carbon that is easy to obtain on coal mine reclamation land are the coal itself and its coal impurities (parting) ameliorants. They are slow to decompose, so the residue can last for a long time in the soil. This study aimed to examine the effect of first-year residue of both coal and parting as ameliorants on the improvement of the physical and chemical properties of coal mine reclaimed soil and soybean yields. A pot study was conducted using a randomized block design with 3 treatments. The treatments tested were residues from the first year of the administration of ameliorant in situ, namely: Control, Bituminous coal ameliorant residue, and parting. Both coal and parting were tested with 5 doses each consisting of 5, 10, 15, 20, or 25 tons ha^{-1}. The results showed that the first-year residue of bituminous coal ameliorant and coal impurities significantly affected some of the chemical properties of coal mine reclaimed soil. Both types of ameliorant residues had a very significant effect on increasing C-organic, humic acid, and total N content. The highest increase in soil organic C was found in soil ameliorated by using bituminous coal residues at 25 tons ha^{-1}, and those by using coal impurities at was 20 tons ha^{-1}. However, treatments did not affect soybean growth and yield.

INTRODUCTION

The nature of the soil on agricultural land is influenced by the organic elements contained therein. The organic matter present in soil plays an important role in long-term soil conservation, or restoration of soil fertility and sustainable agricultural production (Sequi, 1989). The effect of organic elements of improving the physical, chemical and biological properties of the soil cannot be seen in a short time (Miller and Miller, 2000).

It is necessary to add materials containing organic carbon sources to degraded land, in

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this case coal mine reclaimed land. The addition of organic carbon is intended to increase soil organic matter content and improve other soil properties. The main problem that occurs in coal mine reclaimed land is the absence or low content of soil organic matter after coal mining. According to Mummey et al. (2002), the functional destruction of soil ecosystems in mine reclaimed land is caused by the degradation of the physical, chemical, biological and mineralogical properties of the soil. The occurrence of compaction of the soil structure results in poor soil physical properties such as increased bulk density, and decreased capacity of water infiltration into the soil (Ajidirman et al., 2019).

Post-mining soil reactions tend to be more acidic than natural soils. The increased acidity of coal mine reclaimed soil occurs due to the exposure of pyrite minerals so that the contained sulfur undergoes oxidation to sulfuric acid resulting in the pH of the abandoned soil being 2.2-3.5 (Gitt and Dollhopf, 1991; Sabtanto and Suprapto, 2015; Ajidirman et al. al., 2019). Clay with high Al content undergoes destabilization and weathering, thereby releasing Al also results in the increased acidity of the reclaimed soil (Hubová et al., 2017). Soil pH value is an important parameter of soil acidity and is usually used as an indicator of mine soil quality (Wei et al., 2014)

Sources of soil organic carbon can be obtained, among others, from biochar, compost, manure and green manure. In situ, the carbon source that is easily obtained on coal mine reclaimed land is the coal itself and its impurities. Coal is an organic sedimentary rock whose carbon content increases with increasing coal rank, from 65% for lignite to 95% for anthracite (Su et al., 2019). Coal impurities or partings are laminae or layers of non-charcoal rock, usually mudstone or claystone in the coal seam. Parting is formed from sedimentation during flooding in peat which eventually becomes a coal seam (Rahmad and Murad, 2019). Ameliorant bituminous coal contains higher C-organic total than coal impurities, namely 29.46% compared to 19.51%. The content of humic acid in coal is 0.13% whereas the Coal impurity is 0.10%. The C/N of coal is 54 whereas the Coal impurity is 46. The pH of coal is 3.9 whereas the Coal impurity is 4.4 (Ajidirman et al., 2022).

Brown coal mainly consists of polymolecules known as the polyfunctional organic fraction of humic acids. Humic compounds are important long-lasting components of natural soil systems. Humic acid can be a stimulator of plant growth and can store nutrients (Rogova et al., 2013). Coal have no a liming effect on soils, but its carboxylic and phenolic groups in humic derivatives can provide reactive sites for cation exchange which can increase pH buffers and electrical conductivity (Turgay et al., 2011). The addition of a single Reculter (85% brown coal, 10% peat, 4% brown coal ash, and 1% mineral fertilizer) to light clay soils resulted in significantly higher increases in organic carbon and total N content in soil compared to those added with conventional organic wastes such as peat and manure. (Kwiatkowska-Malina, 2015).

The direct or first year effect of bituminous coal ameliorants and coal impurities materials are able to increase pH, C-organic content, N-total, humic acid, and reduce the Al-dd content of coal mine reclaimed soil (Ajidirman et al., 2022). The C/N ratio ranged from 18.94 to 28.26 in coal mine reclaimed land at the end of the first year of research using bituminous coal ameliorant and coal impurities material (Ajidirman et al., 2022) illustrates the continued weathering of the applied ameliorant. As an illustration of the residual effect of providing biochar organic carbon-based ameliorants, Herman and Resigia (2021) reported that biochar residues from rice straw and rice straw compost increased the pH and N -total of ultisol until the second growing season.

Soybean is an annual crop that requires loose soil, a nearly neutral soil reaction, required nutrients, and no acidic cations that damage or poison the roots. The good growth and development of soybean plants shows that the physical and chemical quality of the reclaimed soil increased as a result of the application of coal ameliorants and coal impurities.

MATERIALS AND METHOD

This research started from June to Desember 2021 in the field and the laboratory. Field research was conducted at the Experimental Station of the Faculty of Agriculture, Jambi University. Soil samples obtained from the field were analyzed at the Laboratory of the Faculty of Agriculture, Jambi University, and the Bogor Agricultural Land Resources Center (BBSDLP).

The soil material used was bituminous coal ameliorant in situ and coal impurities in the first year testing soil. The indicator plants used soybean variety Grobogan. Maintenance of soybean plants from pests and diseases used Furadan and Dithane M-45. Soil samples and bituminous coal and coal impurities (parting) ameliorant materials were analyzed in the laboratory. The properties of bituminous coal and parting ameliorant materials used had been published in Ajidirman et al., (2019).

A pot experiment was conducted at the Experimental Station of the Faculty of Agriculture, University of Jambi.. The treatments tested were residues from the first year of the administration of ameliorant in situ, namely: Control (K0), Bituminous coal ameliorant residue (C), and parting (B). Both coal and parting were tested with 5 doses each consisting of 5, 10, 15, 20, and 25 tons ha^{-1}. Each treatment level was replicated 3 times. Treatments were arranged under a randomized block design. Specific codes according to treatment dose for coal are C1, C2, C3, C4, C5; whereas parting being B1, B2, B3, B4 and B5 in the group. Hence, the experiment had 33 trial units.

The placement of experimental pots in the field used the distance between group and rows of 30 cm x 25 cm. The physicochemical variables of reclaimed coal soil observed after being treated include bulk density (gravimetric method, SEM analysis), C-organic (Walkey & Black), pH H_2O (extraction), Al-dd (KCl extraction), N-total (Kjeldahl), C/N ratio, humic acid (NaOH extraction and Calorimeter).

The effect of treatment on the physicochemical properties of reclaimed coal mine soil was analyzed using analysis of variance (ANOVA) at a significance level of 5 per cent (β= 0.05) and 1 per cent (β= 0.01) with the statistical software SPSS Version 26. Significant differences between treatments on the observed variables were further tested using the DMRT (Duncan's multiple range test) with a confidence interval of 95-99%.

RESULTS AND DISCUSSION

The application of organic matter is intended to increase the organic matter content of the soil and to improve the physical and chemical properties of the coal mine reclaimed soil. Changes in the physico-chemical properties of soil residue effects in the first year of testing will provide an overview of the in situ effect of coal ameliorant and coal impurities materials. According to (Giannouli et al., (2009) the main properties for the assessment of coal as a soil amendment are determined by the content of C -organic and humic substances and mineral materials contained therein. The physico-chemical characteristics of the origin of ameliorant used in the first year has been published (Ajidirman et al., 2019). Ameliorant in situ bituminous coal contains higher total C-organic than coal impurities, namely 29.46% versus 19.51%. The humic content of bituminous coal is 0.13% while coal impurities are 0.10% (Ajidirman et al., 2019).

Soil Physico-Chemical Properties of Reclaimed Coal Mine Soil

Bulk Density of Soil

The first year residue from the addition of bituminous coal ameliorant in situ and coal impurity material as shown by the analysis of variance had no effect on the bulk density of the coal mine reclaimed soil. *Bulk density* of coal mine reclaimed soil in the field is 1.50 $g.cm^{-3}$, being very dense, as compared with early/before treatment (1.14-1.19 $g.cm^{-3}$), first year research (1.14 -1.20 $g.cm^{-3}$) and the first year of research residue (1.18-1.22 $g.cm^{-3}$) (Table 1). According to DeLong et al. (2012),

Table 1. Average Physico-Chemical Properties of Soil as a result of the first year residue ameliorant in situ bituminous coal and coal impurities material.

Code of Treatment	First Year Residu						
	Bulk density (g/cm³)	C-org total %	Humic Acid (%)	pH	Al-dd cmol kg⁻¹	N-total %	C/N ratio
A0	-	-	-	-	-	-	-
K0	1.22	0.94f	0.08d	4.73	4.40	0.09e	10.41c
B1	1.22	0.99ef	0.15bc	4.67	4.90	0.09e	11.04bc
B2	1.21	1.13de	0.13c	4.70	5.00	0.10de	11.29abc
B3	1.19	1.21cd	0.16bc	4.67	4.52	0.11cd	11.35abc
B4	1.21	1.33bc	0.19b	4.70	4.86	0.12bc	11.42abc
B5	1.20	1.29cd	0.19b	4.60	4.77	0.11cd	11.69ab
C1	1.22	1.13de	0.16bc	4.60	5.34	0.10de	11.32abc
C2	1.21	1.20cd	0.19b	4.73	4.50	0.11cd	11.32abc
C3	1.18	1.47b	0.15bc	4.63	4.97	0.12b	11.94ab
C4	1.20	1.72a	0.17bc	4.67	4.85	0.14a	12.28a
C5	1.19	1.79a	0.26a	4.60	4.64	0.15a	12.18a

Description: A0 = BV Condition of field reclamation; the numbers followed by the same letter in the same column are not significantly different according to the DMRT test with a 5% confidence level.

native forest soils showed an average specific gravity of 1.05 g cm^{-3}, whereas mine soils ranged from 1.70 to 1.84 g cm^{-3}. The in situ ameliorant residue of bituminous coal and coal impurities material has no effect on *bulk density* because bituminous coal and its coal impurities are non-porous ameliorant materials based on the results of Scanning Electron Microscope (SEM) analysis (Figure 1).

C-Organic

The first year residue from in situ application of bituminous coal and coal impurity material as shown very significantly affected the total C -organic of coal mine reclaimed soil. Residual ameliorant of in situ bituminous coal at doses of 20 and 25 tons ha^{-1} (C4 and C5) showed the highest total organic C content among the residual doses and was greatly different from all other doses (1,72% and 1.79%) (Table 1). Soils in the residue of the ameliorant treatment of coal impurity layer material at a dose of 25 tons ha-1 (B5) had greater total organic C content than from B1 and control (K0); whereas in the residue of the ameliorant in situ treatment of bituminous coal at a dose of 25 tons ha^{-1} (C5) it was greater than those in K0, C1, C2 and C3.

The results of this study indicate that the greater doses of applied ameliorant in situ bituminous coal and coal impurity material, the higher the amount of C-organic in the residue first year. The highest C-organic content was found in the additional dose of 25 tons ha^{-1} (C5), which was 1.79%, while the lowest C-organic content (0.94%) was in the control

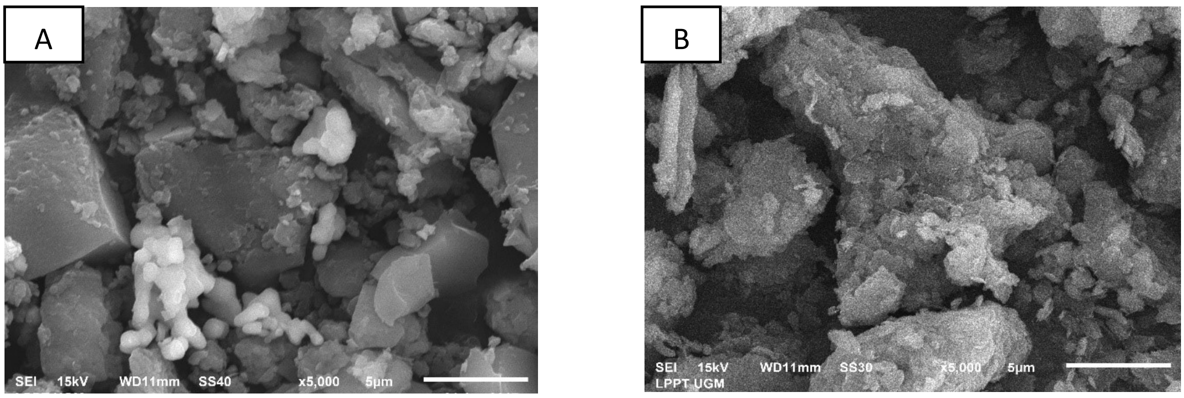

Figure 1: Pictures of SEM Coal (A) and Parting (B) with magnifation of x5.000 with the distance between the particles (5 µm)

treatment (K0). These results are consistent with those reported by Ajidirman et al (2022) that with greater doses of ameliorant in situ bituminous coal and its impurity layer, there was an increase in the C-organic content in coal mine reclaimed soil. In addition, Skodowski et al., (2006) reported that amending the soil of Haplic Luvisols with Reculter originating from brown coal significantly reduced soil acidity and increased the organic carbon content in the soil.

Application of organic matter can increase soil organic carbon content. The increase in C-organic is caused by the decomposition of organic matter from ameliorant in situ bituminous coal and coal impurity which release a number of carbon compounds (C), the main constituent of all organic matter. Subowo (2010) stated that the higher the amount of organic matter in the soil, the longer it takes for the decomposition process by soil microorganisms to leave organic matter residues for further planting. Residues that decompose slowly have a stable impact on soil structure and provide long-term sustainability which results in an increase in soil organic matter content (Cattaneo et al., 2014).

There was a decrease in the C-organic content in the first year residue of ameliorant in situ bituminous coal and coal impurity material because the organic matter provided had undergone further mineralization by microorganisms which resulted in a decrease and loss of organic matter from the soil. Organic matter that has been decomposed will be mineralized into nutrients so that it can be absorbed by plants so that the organic matter content of the soil decreases (Widarti et al., 2015).

Soil Humic Acid Content

The residue from the first year of bituminous coal ameliorant in situ and coal impurity material had a very significant effect on the humic acid content of the coal mine reclaimed soil. The first year residue of ameliorant in situ bituminous coal at a dose of 25 tons ha^{-1} (C5) showed the highest humic acid content (0.26%) among the residual doses and was very significantly different from all doses given with the highest humic acid content. The ratio of soil humic acid content is 0.26% compared to 0.08 to 0.19% (Table 2).

Humic acid content of soil under the residue of the first year ameliorant of coal impurity layer material at a dose of 25 tons ha^{-1} (B5) was greater than those under B1, B2 and control (K0), being similar with those under B4. Humic acid content of soil under the first year residue of ameliorant in situ bituminous coal dose of 25 ton ha-1 (C5) is greater than those under K0, C1, C2, C3 and C4.

The increase in humic acid content comes from the decomposition of bituminous coal and the impurity layer of the coal supplied. Changes in the value of the C/N ratio indicate that weathering has occurred. Humic acid can be obtained from any source of organic matter, one of which is bituminous coal at different maturation stages. The research results of Ajidirman et al (2022) showed that the humic acid content of coal mine reclaimed soil increased with increasing doses of ameliorant applied. Coal contains up to 50% humic substances, most of which are humic acids (Krumins et al., 2017). Khan et al. (2014) reported that the application of humic acid derived from three lignite coals (black, brown and half white) can restore soil humic acid content. Based on the recovery of humic acids and the availability of micronutrients, black coal can be classified as superior quality.

Application of humic acid affects soil physical and chemical properties differently due to differences in their origin, composition, and formulation. Humic acids play an important role in soil fertilization which contributes to various soil properties including chelation, buffering, clay-organic mineral interactions and cation exchange capacities which are important for soil quality (Selim & Ali Mosa, 2012). According to various studies, lignite coal has a high humic acid content and contains various aromatic groups that are difficult to decompose (Tahir et al., 2011). Humic acids are more resistant to the activity of soil microorganisms (Syafrullah, 2019), hence can increase soil C-organic content and improve soil physical, chemical and biological properties (Lüttge et al., 2005).

Humic acid is the most important fraction of soil organic carbon, and is an important factor for maintenance of soil fertility because it is the main constituent of organic fertilizer (Chefetz et al., 2002) which can add nutrients, improve soil aggregation, and stimulate microbial diversity (Carpenter-Boggs et al., 2000). Humic acids extracted from various organic matter are mostly used in agriculture as biofertilizers and soil improvers (Shahzad et al., 2015)(Chen et al, 2004).

pH of Soil

The first year residue from the in situ application of bituminous coal and coal impurity material had no significant effect on the pH of the coal mine reclaimed soil. Initial coal mine soil pH/before treatment (4.36-4.65), first year research following reclamation (4.80-5.05) and first year residue (4.60-4.73) (Table 1). The increase in total organic C due to the in situ ameliorant treatment of bituminous coal and coal impurity material in the first year of study was followed by an increase in soil pH. However, this did not occur in the first year of residue research where soil pH decreased compared to the first year of research. The decrease of soil pH in the first year residue of bituminous coal in situ and coal impurity material ameliorants occurred at higher doses rather than those at lower ones. The decrease in pH is thought to be due to the oxidation of sulfur during the decomposition process of the ameliorant that has been administered. Bayer et al. (2001) stated that the rise and fall of soil pH is a function of H^+ and OH^- ions, if the concentration of H^+ ions in the soil solution increases, the pH will decrease and if the concentration of OH^- ions rises, the pH will rise.

Al-dd

The first year residue from the addition of bituminous coal ameliorant in situ and coal impurity material had no significant effect on the Al-dd of coal mine reclaimed soil. Al-dd pre-treated coal mine reclaimed soil (5.97-6.49 cmol kg^{-1}), first year research (4.61-5.70 cmol kg^{-1}) and first year residue (4 .40-5.34 cmol kg^{-1}), although on average it has decreased as compared to those in the beginning and in the first year (Table 1).

The results of this study indicated that there was a decrease in Al-dd from the beginning to the first year of residual research, but it was still at very high levels. A lower C/N ratio means that organic matter will decompose faster in the soil and produce organic acids which will form chelate compounds with free Al^{3+} in the soil, so that the exchangeable Al^{3+} decreases.

N-Total

The first year residue of bituminous coal ameliorant in situ and coal impurity material had a very significant effect on the total N of coal mine reclaimed soil. Ameliorant residue in situ bituminous coal at a dose of 25 tons ha^{-1} (C5) showed total N content (0,15%) the highest among the residual doses and was very significantly different from all doses given except for ameliorant residue in situ bituminous coal at a dose of 20 tons ha^{-1} (C4) with a total N content of 0.14% (Table 2). The residual ameliorant material of the coal impurity layer at a dose of 25 tons ha^{-1} (B5) was very significantly different from B1, B2 and control (K0) while the ameliorant residue in situ bituminous bituminous coal at a dose of 25 tons ha^{-1} (C5) was different very real with K0, C1, C2 and C3. The increase in soil N content in this study was due to the presence of N content in ameliorant in situ bituminous coal and coal impurity material.

The first year residue from in situ ameliorant application of bituminous coal and coal impurity causes an increase in soil total N. Ajidirman et al (2022) reported that the total N of coal mine reclaimed soil increased with increasing doses of ameliorant applied and in line with an increase in C-organic and humic acid. Ma'shum et al. (2003) stated that the availability of nitrogen nutrients is directly affected by organic matter, in other words the addition of organic matter can increase total N.

C/N ratio

The residue from the first year of in situ bituminous coal ameliorant and coal impurity material had a **significant** effect on the C/N ratio of coal mine reclaimed soil. Residual ameliorant of in situ bituminous coal at a dose of 20 tons ha^{-1} (C4) showed the highest C/N ratio (12,28%) among the residual doses and was significantly different from those at all other doses given except those at ameliorant residue in situ bituminous coal at a dose of 25 tons ha^{-1} (C5) with the highest C/N ratio (12.28%, Table 1). The soil C/N ratio under ameliorant residue of coal impurity layer material at a dose of 25 tons ha^{-1} (B5) was significantly different from B1 and control (K0) while for ameliorant residue in situ bituminous coal at a dose of 25 tons ha^{-1} (B5) was greater than those under K0, C1,C2.

The soil C/N ratio indicates the rate of decomposition of organic matter in the soil and is also related to the availability of decomposed N. A high C/N ratio is associated with high stability and aromaticity and a high degree of humification of humic acids (Barancikova et al., 1997). The effect caused by the addition of external organic matter with a high C:N ratio can also cause the existing organic matter to mineralize faster than usual, releasing nitrogen that has been trapped there (Shahzad et al., 2015). This shows that as the C content in the soil increases, the total N content in the soil will also increase (Rusdiana and Lubis, 2012). If the C content in the soil is higher than the total N content in the soil, the C/N ratio in the soil will be higher, whereas if the content of C and N in the soil is relatively high then the value of soil C/N ratio will be low. Changes in the value of the C/N ratio indicate that weathering has occurred.

Soybean Growth and Yield As Affected The First Year Residual Ameliroant In Situ Coal and Its Impurity Layer

Plant Height

The residue from the first year of in situ administration of bituminous coal ameliorant and coal impurity material as shown by analysis of variance had no effect on soybean plant height. The height of soybean plants in the first year study (37.48-42.13 cm) and the first year residue research (28.73-33.77 cm) can be seen in Table 2. The soybean plants used in the first year residue study were ameliorant in situ bituminous coal and coal impurity material, namely the Grobogan variety, while the first year of research used the Anjasmoro soybean variety. Plant height in the first year research of ameliorant in situ bituminous coal residues and their impurity layer material decreased from the first year research. The decrease in plant height is thought to be due to coal mine reclaimed soil, the first annual residue of ameliorant in situ bituminous coal and coal impurity material which has a high Al-dd content (Table 2) so that plants cannot grow normally which has an impact on soybean plant height.

Verlinden, et al. (2009) stated that using 12% humic material was able to increase plant nitrogen and phosphorus uptake. Humic acid application significantly increased plant growth in coarse-textured and medium-textured soils and resulted in higher root and shoot mass (Ciarkowska et al., 2017).

Yields

The first year residue from the addition of bituminous coal ameliorant in situ and coal impurity material did not affect soybean yield. The results of the first year research soybeans (1.57-2.03 tons ha^{-1}) (Ajidirman et al., 2022) and the first year research residues (0.38-0.50 tons/ha) (Table 2). The low yields of soybean research residues in the first year in situ rock

Table 2. Average plant height soybean and yields soybean as a result of the first year residue ameliorant in situ bituminous coal and coal impurities material

Code of Treatment	First Year Residu	
	Plant Heighs	Soybean Yields
K0	28.73	0.40
B1	33.77	0.38
B2	32.90	0.40
B3	29.43	0.42
B4	33.57	0.43
B5	31.43	0.44
C1	32.00	0.38
C2	32.17	0.44
C3	31.67	0.46
C4	33.70	0.46
C5	32.13	0.50

bituminous coal and coal impurity material is caused by the high Al-dd content contained in the coal mine reclaimed soil which inhibits the growth of soybean plants and hamper the formation of soybean pods and the few branches that appear.

Under the levels of Al-dd in this study, the soybean plants were not poisoned and were still able to grow. It is suspected that Al-dd is bound in the form of C-organic complex as shown by Al pyrophosphate data processing. The decomposition of organic matter in the treatment of bituminous coal ameliorant in situ and coal impurity material has the ability to bind Al-dd in a complex structure that is difficult to dissolve, consequently resulted in a decrease of Al activity. The effect of organic matter in reducing Al-dd is related to the organic acids produced during the decomposition process of organic matter. One of the organic acids produced is humic acid which can form chelates or organic Al complexes (Tan, 1993). According to Heil (2005), humic acid has a direct effect in improving metabolic processes in plants, such as increasing the rate of plant photosynthesis. The addition of humic acid increases the yield and quality of plant varieties by acting on mechanisms involved in cellular respiration, photosynthesis, protein synthesis, water and nutrient absorption and enzyme activity (Chen et al., 2004).

CONCLUSION

The residue of the first year of ameliorant in situ bituminous coal and coal impurity can still improve some of the physico-chemical properties of coal mine reclaimed soil in terms of increasing soil organic C, humic acid, total N. The greatest increase in soil C-organic residue in the first year of ameliorant in situ bituminous coal occurred at a dose of 25 tons ha-1 (C5), while in the coal impurity layer material at a dose of 20 tons ha-1 (B4).

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